We claim:

1. An apparatus for optically coupling light between an optical fiber and a substrate, comprising:

a waveguide grating coupler disposed on the substrate
and
an optical fiber comprising: a core and a cladding, with an angled tip,
where the angled tip of the fiber:
is positioned on the surface of a substrate with the core of the fiber substantially parallel to the surface of the substrate, and the cladding on the longer side of the angled tip is adjacent to the surface of the substrate,
and
has a reflective surface with an angle of less than 45 degrees to the surface of the substrate, and the reflective surface is positioned adjacent to the waveguide grating coupler disposed on the substrate.

2. An apparatus according to claim 1, wherein the reflection of light at the reflective surface is substantially total internal reflection.

3. An apparatus according to claim 1, and further comprising a coating on the exterior of the reflective surface, where the material comprising the coating is selected from one of the following: a dielectric, a plurality of dielectric layers, epoxy, a metal and a first layer comprised of metal and a second layer comprised of epoxy.

4. An apparatus according to claim 3, wherein the metal is selected from one of the following: aluminum and gold.

5. An apparatus according to claim 1, wherein the shape of the reflective surface is substantially flat.

6. An apparatus according to claim 1, wherein light reflecting off the reflective surface and propagating to the substrate is a diverging beam of light.

7. An apparatus according to claim 1, wherein light propagating from the waveguide grating coupler to the reflective surface is a converging beam of light.

8. An apparatus according to claim 1, wherein the waveguide grating coupler couples light between the fiber and a planar waveguide disposed on the substrate.

9. An apparatus according to claim 1, and further comprising a flat section on the cladding adjacent to the angled tip of the fiber, where the flat section:
is oriented parallel to the core of the fiber,
is positioned on the longer side of the angled tip,
is aligned adjacent to and on top of the waveguide grating coupler,
and

is positioned in substantial contact with the surface of the substrate.

10. An apparatus according to claim 9, wherein the flat section forms a stigmatic lens in the optical path between the reflective surface of the angled tip of the fiber and the surface of the substrate.

11. An apparatus according to claim 1, and further comprising mechanical bonding of the fiber to the substrate with epoxy.

12. An apparatus according to claim 1, and further comprising mechanical bonding of the fiber to a pedestal with epoxy.

13. An apparatus according to claim 12, and further comprising mechanical bonding of the pedestal to the substrate with epoxy.

14. An apparatus according to claim 1, and further comprising bonding of the fiber to a connector with one of the following: a mechanical bond and epoxy.

15. An apparatus according to claim 14, and further comprising bonding of the connector by one of the following:
using epoxy to bond the connector to the substrate,
using epoxy to bond the connector to a package enclosing the substrate,
using solder to bond the connector to the substrate,
using solder to bond the connector to a package enclosing the substrate,
using a mechanical bond to bond the connector to the substrate

and

using a mechanical bond to bond the connector to a package enclosing the substrate.

16. An apparatus according to claim 1, and further comprising a metallic coating applied to a section of the cladding of the fiber, where the metallized section of the cladding is not in the optical path of light propagating between the reflective surface and the substrate.

17. An apparatus according to claim 16, and further comprising mechanical bonding of the metallized section of the cladding of the fiber to the substrate with solder.

18. An apparatus according to claim 16, and further comprising mechanical bonding of the metallized section of the cladding of the fiber to a pedestal with solder.

19. An apparatus according to claim 18, and further comprising mechanical bonding of the pedestal to the substrate with a material selected from one of the following: epoxy and solder.

20. An apparatus according to claim 1, and further comprising an automated system for the alignment of the angled tip of the fiber to the waveguide grating coupler on the substrate.

21. An apparatus according to claim 20, and further comprising an automated system for the alignment of the angled tip of the fiber in the longitudinal direction of the fiber to the waveguide grating coupler on the substrate.

22. An apparatus according to claim 20, and further comprising an automated system for the alignment of the angled tip of the fiber in the lateral direction of the fiber to the waveguide grating coupler on the substrate.

23. An apparatus according to claim 20, and further comprising an automated system for the alignment of the angled tip of the fiber with respect to the height of the fiber above the waveguide grating coupler on the substrate.

24. An apparatus according to claim 1, wherein the optical fiber is selected from one of the following: a single mode fiber and a polarization maintaining fiber.

25. An apparatus according to claim 1, wherein the optical fiber is a polarization maintaining fiber (PMF) with a mode polarized parallel to the surface of the substrate.

26. An apparatus according to claim 1, wherein the substrate is selected from the group comprising: silicon, silicon on insulator (SOI), silicon on sapphire (SOS), silicon on nothing (SON) and

a first layer of monocrystalline silicon,
a second layer of dielectric material disposed on the first layer,
a third layer of monocrystalline silicon disposed on the second layer,
a fourth layer of dielectric material disposed on the third layer,
a fifth layer of monocrystalline silicon disposed on the fourth layer.

27. A method of fabricating an apparatus for coupling light between an optical fiber and a waveguide grating coupler disposed on a substrate, comprising:

forming an angled tip with a reflective surface on the fiber by cutting the fiber at an angle of less than 45 degrees with respect to the core of the fiber,

positioning the longer side of the angled tip of the fiber on top and adjacent to the waveguide grating coupler,
and
bonding the angled tip of the fiber to the substrate.

28. The method of claim 27, wherein forming the angled tip further comprises:

flattening the reflective surface by polishing the reflective surface, after the fiber has been cut.

29. The method of claim 27, wherein forming the angled tip further comprises:

coating the reflective surface with a coating, after the fiber has been cut, where the coating is selected from one of the following: a dielectric, a plurality of dielectric layers, epoxy, a metal and a first layer comprised of metal and a second layer comprised of epoxy.

30. The method of claim 27, wherein positioning further comprises:

propagating a light through the optical fiber towards the reflective surface, and
aligning the angled tip of the fiber with respect to the waveguide grating coupler by maximizing the amount of light coupled from the reflective surface through the waveguide grating coupler.

31. The method of claim 27, wherein positioning further comprises:

propagating a light through the waveguide grating coupler towards the reflective surface,
and
aligning the angled tip of the fiber with respect to the waveguide grating coupler by maximizing the amount of light coupled to the optical fiber through the reflective surface.

32. The method of claim 27, wherein bonding further comprises:

using epoxy to bond the angled tip of the fiber to the substrate.

33. The method of claim 27, wherein bonding further comprises:

using epoxy to bond the angled tip of the fiber to a pedestal
and
using epoxy to bond the pedestal to the substrate.

34. The method of claim 27, wherein bonding further comprises:

bonding the angled tip of the fiber to a connector using one of the following: epoxy, solder and a mechanical bond
and
bonding the connector to the substrate using one of the following: epoxy, solder and a mechanical bond.

35. The method of claim 27, wherein bonding further comprises:

bonding the angled tip of the fiber to a connector using one of the following: epoxy, solder and a mechanical bond
and
bonding the connector to a package enclosing the substrate using one of the following: epoxy, solder and a mechanical bond.

36. The method of claim 27, wherein bonding further comprises:

applying a metal coating to a section of the cladding of the fiber, where the metallized section of the cladding is not in the optical path of light propagating between the reflective surface and the waveguide grating coupler disposed on the substrate,

and

bonding the metallized section of fiber to the substrate with solder.

37. The method of claim 27, wherein bonding further comprises:

applying a metal coating to a section of the cladding of the fiber, where the metallized section of the cladding is not in the optical path of light propagating between the reflective surface and the waveguide grating coupler disposed on the substrate,

bonding the metallized section of fiber to a pedestal with solder,

and

bonding the pedestal to the substrate with a material selected from one of the following: epoxy and solder.

38. The method of claim 27, wherein bonding further comprises:

forming a flat section on the cladding adjacent to the angled tip of the fiber, where the flat section is on the longer side of the angled tip, and the flat section is oriented parallel to the core of the fiber,

aligning the flat section adjacent to and on top of the waveguide grating coupler,

positioning the flat section in substantial contact with the surface of the substrate,
and
bonding the planar section to the substrate with epoxy.

39. The method of claim 27, wherein the optical fiber is a polarization maintaining fiber (PMF) and forming the angled tip further comprises:

selecting the mode of the PMF to be propagated through the apparatus, where the selected mode is polarized parallel to the surface of the substrate, and
forming the angled tip with a reflective surface on the fiber by cutting the fiber at an angle of less than 45 degrees with respect to the plane of the selected mode.